LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

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SLC Arm Cavity Baffle Assembly & Installation Hazard Analysis

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CHANGE LOG

Date, version	Summary of Changes
2011-12-14 V5	• Updated document format • Added Change Log • Updated hazards to current Installation Procedure • Update Approval Signatures list
2011-12-14 V6	• Update Table of Figures and corrected Figure links. • Color coded Mitigated Risk Index • Clarified use of Safety Glasses used in Section 5.2

Table of Contents

Table of Figures

1 Scope

This document covers safety concerns related to the assembly and installation of the Arm Cavity Baffle onto an inverted platform. This inverted platform can be any of the following:

- Balancing table structure in clean room
- BSC-ISI Stage-0 structure on the SEI/SUS mechanical test stand (as part of the cartridge installation),
- BSC-ISI Stage-0 structure in the BSC chamber
- An inverted platform in Room 318 of Downs Lab for testing the first article

This procedure must be read before beginning the assembly or the installation of the Arm Cavity Baffle.

Note that the installation of the Arm Cavity Baffle is one element of the Stray Light Control (SLC) subsystem. The installation plan for SLC components is covered in “SLC and Viewports Installation plan”, LIGO-E1000099.

2 Summary of Hazards

The major hazards to be aware of in the assembly and installation of the Arm Cavity Baffle include:

1) Personnel strain from lifting the baffle (4E)
2) Sudden release of tensioned springs (4D)
3) Impact damage to the quad suspension from a swinging baffle assembly
4) Dropped loads
5) Overstress/damage of the flexure
6) Pinching/ Cutting of hands against the parts being assembled
7) Bumping one's head or body in the tighter spaces of the viewport adapter flanges and mode cleaner tubes
8) Contamination hazard of the vacuum system

Each hazard is described in detail later in the document.

3 Overview

A Solid Works model of the Arm Cavity Baffle (ACB, D1100812) is shown in Figure 1. The baffle structure is suspended from the ISI Stage 0 (or a platform representing this interface) by a single flexure pendulum attached to a cantilevered blade spring. The ACB is ultimately installed into each chamber which has a test mass optic (the installation in WBSC8 is depicted in Figure 1. The weight of the suspension mechanism (D1001011) is approximately 50 lbs. The weight of the suspended baffle (D1100824) is approximately 95 lbs, or with the balance masses, approximately 130 lbs.

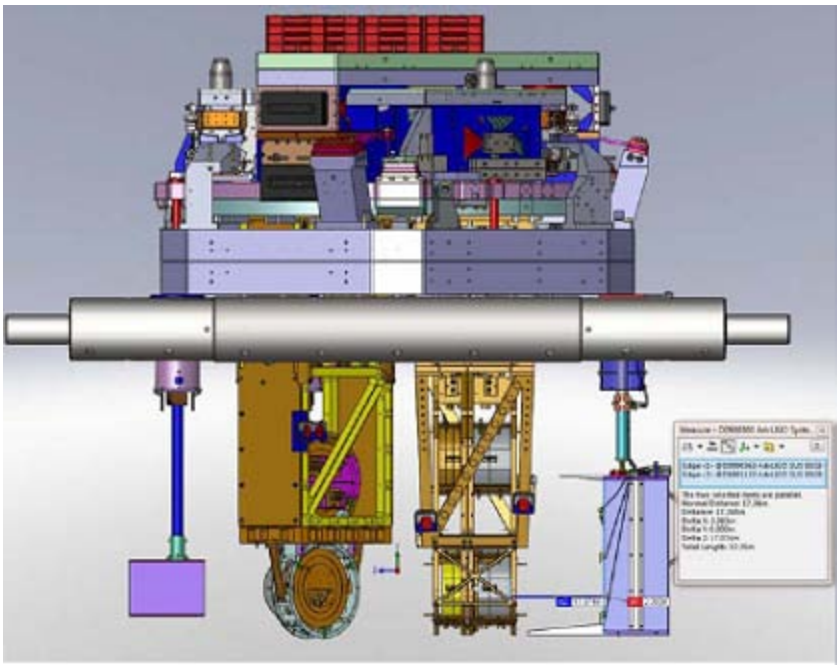

Figure 1: Arm Cavity Baffle Installed in BSC8-H2

During the assembly and installation of the Arm Cavity Baffle, a task leader should be assigned to supervise all activities. The task leader needs to be experienced with suspensions and their accompanying hardware.

This assembly and installation requires overall common sense and good lab practices. Personnel must have good working knowledge of how to safely use the tools associated with the build. All personnel must have appropriate safety training to work at a LIGO facility.

3.1 ACB Assembly Procedure

The suspension mechanism (D1001011), consisting of:

a) Blade Assembly (D1001005),
b) Upper (D1002582) and Lower (D1001007) Tube Assemblies, joined together

c) Damping Tube Assembly (D1002563)

3.1.1 ACB Blade Preload

The blade spring bracket and the blade spring will be mounted temporarily to the interface plate rotated 180 deg to its normal position; the interface plate is clamped to a suitable flat table surface so that the blade spring extends outward beyond the edge of the table, as shown in the Figure 2. Pre-loading weights of approximately 140 lbs will be hung from the tip of the blade spring until the blade spring bends into an arc that matches the surface of the ACB bend fixture; after which, the bend fixture will be attached with bolts to the blade.
Following the pre-bending procedure, the pre-bent blade and the blade mounting bracket will be properly attached to the interface plate; then, the bend fixture will be removed.

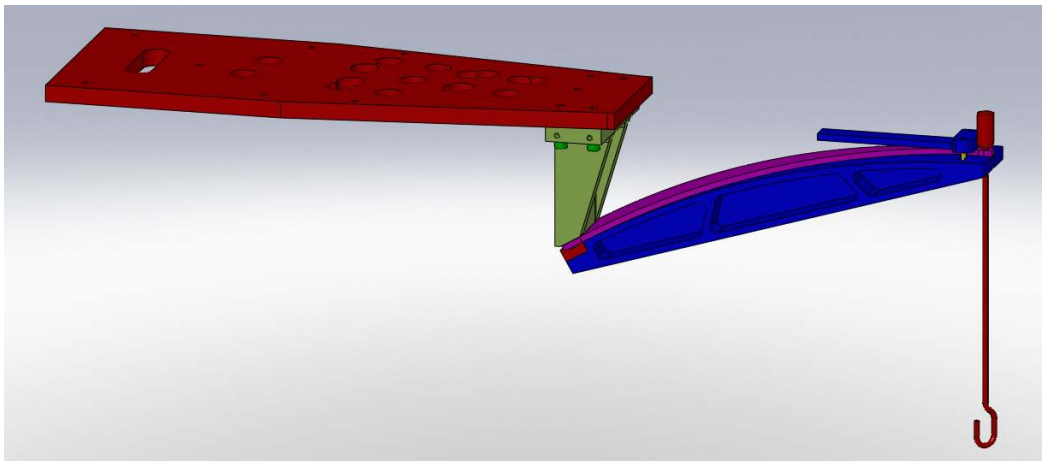

Figure 2: D1001005: ACB Blade Assy in Bending Configuration

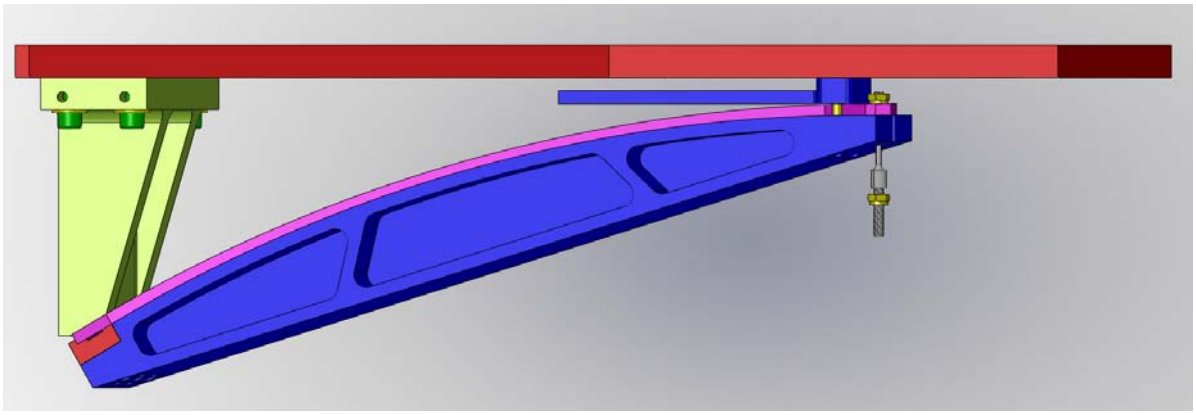

Figure 3: D1001005: ACB Blade Assy in Post-bending Configuration

During this operation, a hazard exists from the sudden release of the tensioned spring, which will be discussed in section 5.

3.1.2 ACB Suspension Assembly

The ACB suspension assembly is shown in Figure 4.

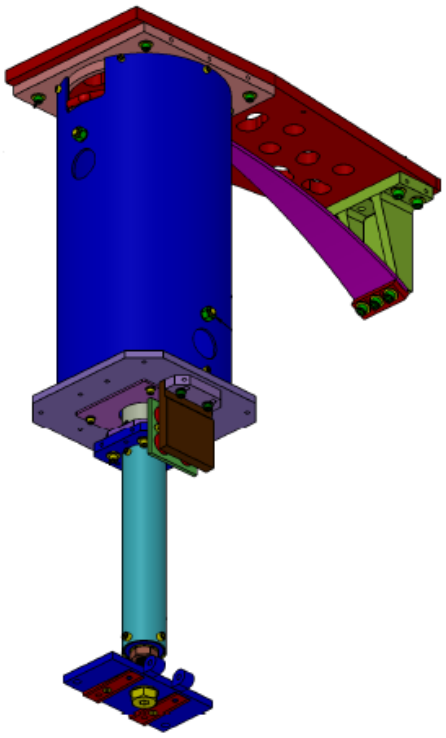

Figure 4: ACB Suspension Assembly

3.1.3 ACB Box Assembly

The ACB box structure is shown in Figure 5.

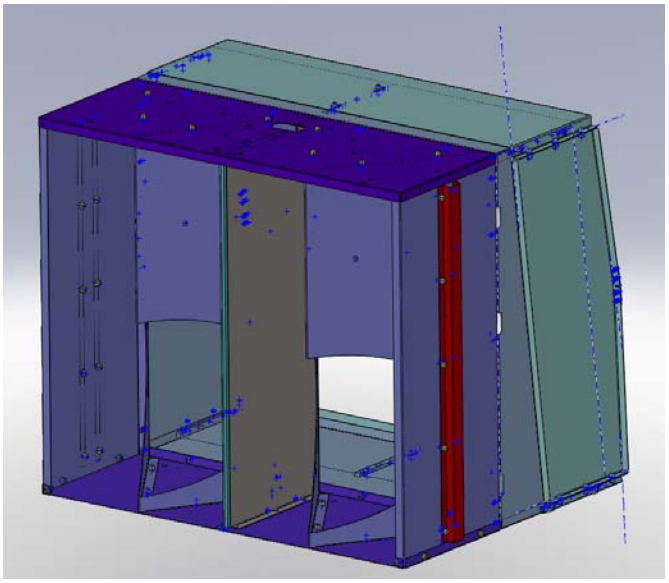

Figure 5: ACB Box Assembly

3.1.4 ACB Balancing

In order to add the proper balance weights and position them on the ACB, the entire ACB assembly, including the suspension assembly and the box assembly, must be attached at the hinge plate and hung freely from an overhead platform by mounting the ACB interface plate to the overhead plate with dog clamps.

3.1.4.1 Suspension Assembly Attachment to Overhead Plate

Two people will mount the ACB suspension assembly into the installation stand, and place the suspension and installation stand on the lift table prior to attaching the ACB suspension to the overhead plate. The installation stand is secured to the lift table with dog clamps.

The assembled suspension portion of the ACB is lifted up to the overhead plate with the expandable installation stand sitting on top of the lifting table; two persons will pull up on the lift bars of the telescoping installation stand. During this procedure, the potential hazard of back strain may occur, and there is a potential hazard of injury from a heavy falling object.

The ACB interface plate will be attached securely to the overhead plate by means of dog clamps. During this procedure, there is a potential hazard of finger and hand injury.

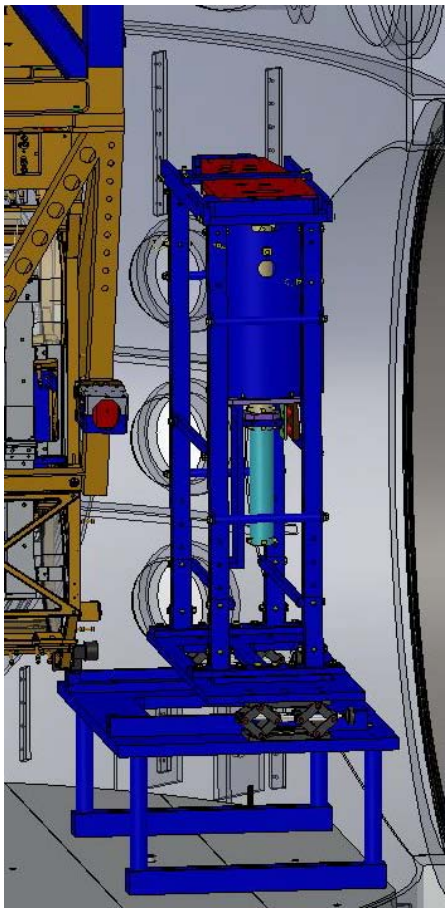

Figure 6: ACB suspension assy in installation stand on top of lift table

The expandable vertical support members of the installation stand and the scissor jacks of the lift table will be used to lift the ACB suspension until it mates against the overhead plate.

Figure 7: ACB suspension assy attached to the overhead plate

3.1.4.2 ACB Box Assembly Attachment

The ACB box assembly is lifted by two people and placed on the lift table, as shown in Figure 8.

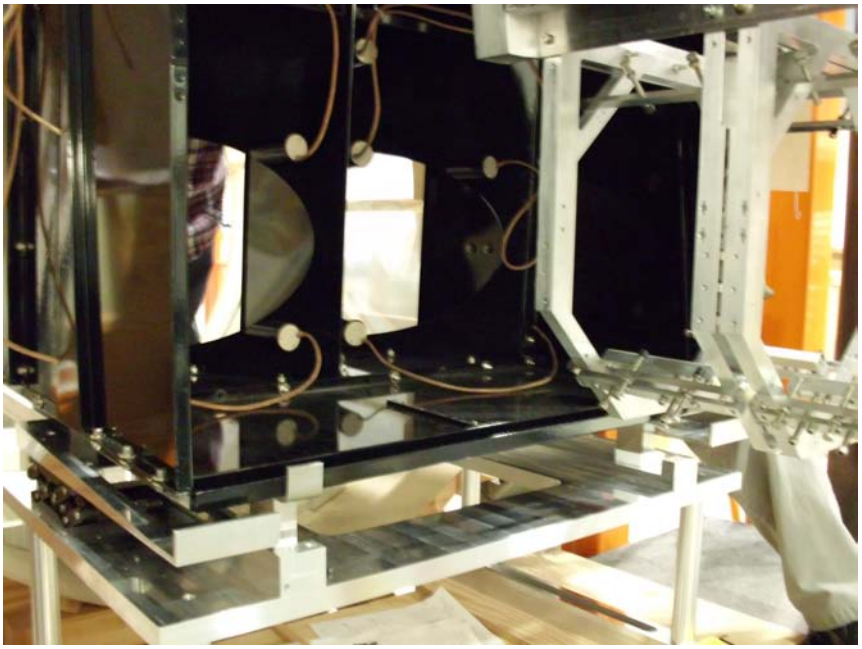

Figure 8: ACB Box placed on top of lift table

During this procedure, the potential hazard of back strain may occur, and there is a potential hazard of injury from a falling heavy object.

Raise the ACB box by turning the screws of the scissor jacks until the hinge plate half attached to the ACB box mates with the hinge plate half attached to the suspension assembly, and insert the hinge pin.

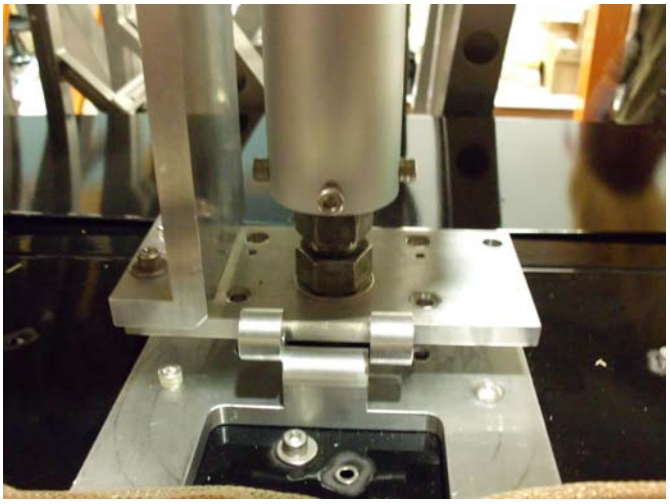

Figure 9: Mating the hinge plate halfs

Add the appropriate balance weights and adjust the position of the weights until the ACB box hangs vertically and freely within the earthquake stop restraints.

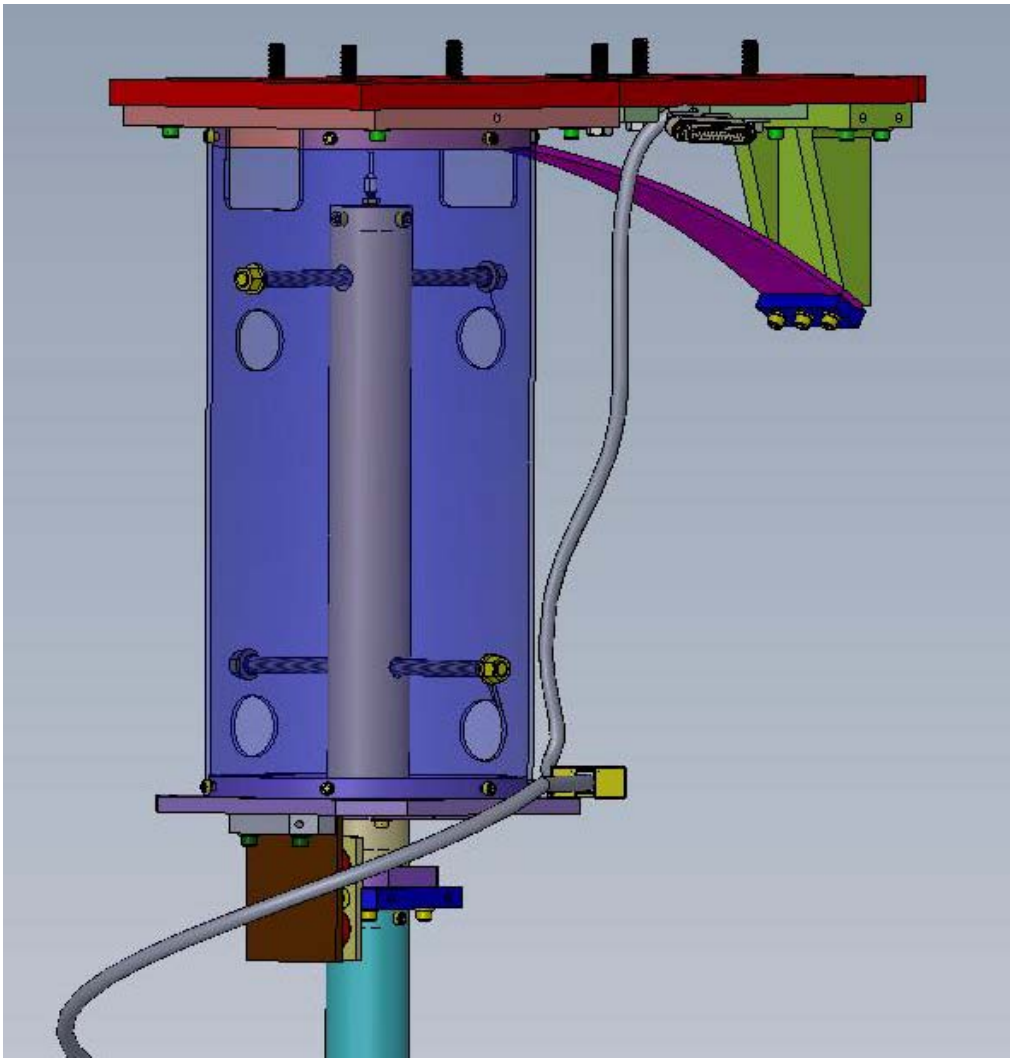

Figure 10: ACB hanging freely within earthquake stops

3.2 ACB Installation Procedure

The ACB installation in the BSC chamber follows the same steps as the balancing procedure, except that the balancing steps will already have been accomplished and will not be repeated in the chamber. The installed ACB is shown in Figure 11. After hanging the ACB box to the ACB suspension, the insertion rails, the translating sled, and the lift table assembly are removed from the chamber.

The potential hazards that may occur during the installation procedure are the same as for the balancing procedure; in addition, there is the additional hazard of contaminating the vacuum environment.

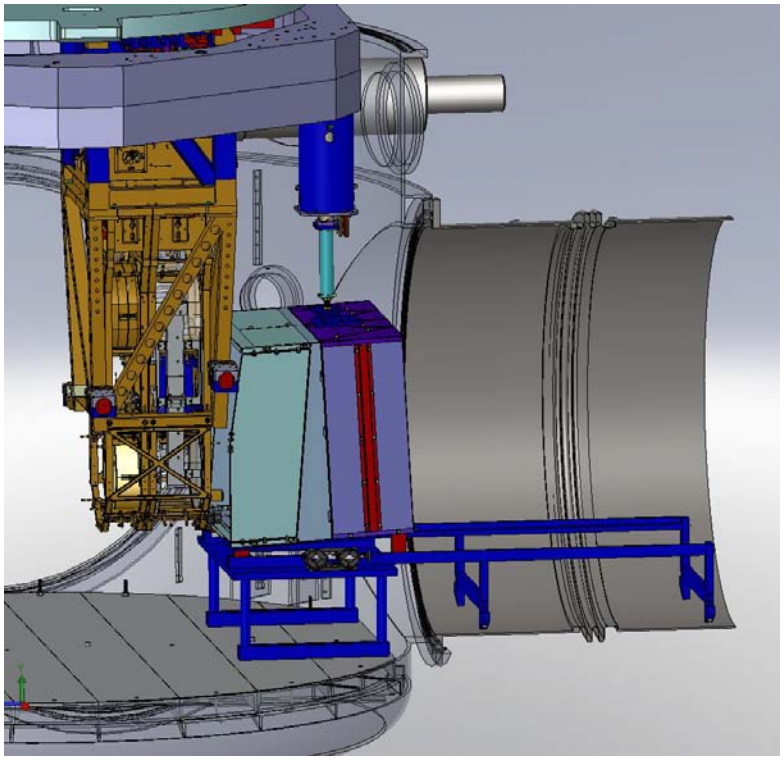

Figure 11: ACB sitting on lift table and connected to the ACB suspension

4 Related Documentation

SLC Arm Cavity Baffle Assembly Procedure (LIGO-E1100867)
SLC Arm Cavity Baffle Installation Procedure (LIGO- E1100810)
SLC and Viewports Installation Plan (LIGO-E1000099-v1)
Advanced LIGO Safety: Processes and Guidelines (LIGO-M070360)
LIGO Project System Safety Plan (LIGO-M950046)
LIGO Hanford Observatory Contamination Control Plan (LIGO-M990034)
Chamber Entry/Exit Checklist (LIGO-E000065)
LIGO Hanford Observatory Laser Safety Plan (LIGO-M020131)
LLO Safety Procedure documents: http://www.ligo-la.caltech.edu/contents/internalmain.htm
LIGO Observatories Operations Safety and Environmental Protection Manual - M980242-v2
General Safety Rules for aLIGO De-Install-Install Activities - T1000629-v2

5 Hazard Analysis

Each hazard and mitigation approach or measure is discussed in this section and listed in the severity table in the next section.

5.1 Strain from lifting assembly

The total weight of the Arm Cavity baffle is approximately 130 lbs. The baffle will be installed in two separate parts: the Suspension Assembly and the Baffle Box Assembly. The following procedures may cause a strained back or pinched finger hazard.

5.1.1 Placing Suspension Assembly in Installation Stand

The Suspension Assembly is assembled upside down and then lifted by two people from the assembly table top and rotated 180̊ with the interface plate resting on the top brackets of the Installation Stand, and secured with an upper clamp and side beam safety plates.

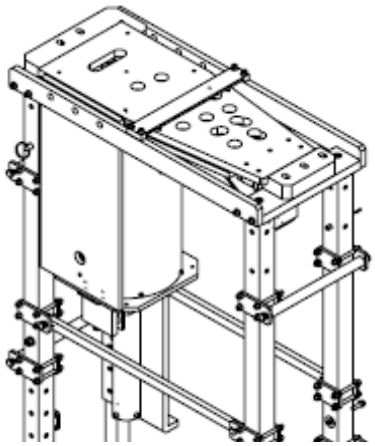

Figure 12: ACB suspension assy placed on top of the installation stand

The complete Suspension Assembly weighs approximately 53 lb, and the unbalanced weight of the assembly can add awkwardness to the lift. Difficulty with the lift can be mitigated by utilizing two people for the lift and having a verbal recitation stating 1) where each person will hold the assembly 2) each person's movement and path during the lift and 3) final placement in the Stand.

5.1.2 Placing Suspension Assembly and the Installation Stand on Lift Table

The complete Suspension Assembly in the Stand weighs approximately 100 lb. It must be carried and placed on top of the lift table. The combined assembly must be lifted and carried by two people. Handles have been provided for ease in the lift and transport.

5.1.3 Lifting the Baffle Box

Whenever heavy objects are lifted by more than one person, the group of people who are lifting the load together should be paired with equal height and strength, if possible, to avoid unbalancing or overloading any single individual.

Prior to entering and carrying the ACB box down the manifold tube to the BSC, ensure that proper ventilation exists in the tube by using the 4-gas meter to check for proper O2 levels.

The complete ACB Box weighs approximately 100 lb. The Baffle Box will be transported down the Y-Manifold Tube which is 27 meters long and 72 inches in diameter; two people will carry the ACB Box using a sedan chair-style lift to mitigate the strain of lifting. The path from starting point to destination must be clear.

For installation in the BSC, the ACB Box will be lifted approximately 12 inches inside the spool piece by 2 people using the sedan chair bars, and placed onto the Slider Frame on top of the rails.

For installation on the overhead balancing plate, the ACB Box will be lifted approximately 12 inches by 2 people, and placed onto the lift table.

5.1.4 Handling of Installation Tooling

The Wedge Lift, Baffle, Suspension Table will be brought into the BSC chamber and placed on the floor of the BSC at the entrance to the spool; the individual parts weigh < 40 lbs, and it will be assembled in place or carried in by four people.

5.2 Sudden Release of Tensioned Spring

The Arm Cavity Baffle suspension utilizes a blade spring that is placed under bending tension during its assembly. The spring is loaded with approximately 130 lbs by the suspended baffle. In the event that the tension in the springs should suddenly be released, the blade tip will spring up against the bottom side of the top mounting plate, shown in Figure 3; this will prevent the spring from traveling further.

If the sudden release in tension is caused by the suspension flexure breaking, the baffle will be caught by the earthquake stops, as shown in Figure 10, and will not fall farther than a 1/4 inch.

Safety glasses must be worn when the spring is being placed in tension during the assembly of the baffle suspension, in the unlikely event that the tooling breaks or slips, resulting in the release of a fast moving part. Once the blade spring is installed into the Blade Assembly (D1001005), joined to the Upper (D1002582) and Lower (D1001007) Tube Assemblies, and the Damping Tube Assembly (D1002563), as shown in Figure 13, safety glasses are no longer required since the spring is constrained.

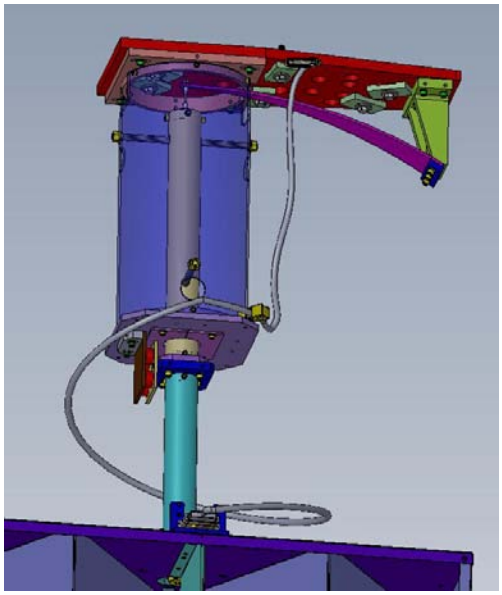

Figure 13: Arm Cavity Baffle Vertical Spring Assy.

5.3 Damage to the Quad Suspension and Mirror

The ACB will be installed inside the BSC in close proximity to the quad suspension structure and the COC mirror. A protective barrier will be installed temporarily between the ACB and the quad suspension structure during the initial phase of installing the ACB; in spite of this protective barrier, dropping a tool or object onto the quad structure may cause serious damage to the structure or to the supporting elements of the mirror. After the alignment of the ACB is complete, it will be swung back out of the way to allow access to the HR surface of the COC mirror by a person who will remove the first contact coating that protects the mirror. Finally, the ACB will be swung back down to vertical from its temporary swung back position; during this last operation, the COC mirror is unprotected and is extremely vulnerable to damage if any object or body part touches the mirror. Similarly, care must be taken by the ACB installation crew when they exit the chamber.

5.4 Damage Caused by Dropped Loads

The assembly and installation involves manual manipulation of relatively heavy objects (up to 130 lbs). The potential exists for dropping these loads which would likely damage the parts and represents a potential injury to feet and toes. Steel toed shoes must be worn during the assembly and installation.

5.4.1 Suspension Assembly

The Suspension Assembly will be assembled upside down on a table top and then placed into the installation stand. The suspension may be dropped and cause injury to the personnel supporting it.

5.4.2 Baffle Box

The baffle box must be placed on top of the lift table during installation onto the overhead plate or inside the BSC. The box may be dropped and cause injury to the personnel supporting it.

5.5 Overstress/damage to the flexure

The suspension flexure rod can be damaged by over torqueing or tightening during the assembly process. This risk is mitigated by following the assembly procedure steps carefully, including the prescribed torque value.

The flexure can be damaged by applying a large bending load before the suspension limiters (stops) have been installed. This risk is mitigated by following the assembly procedure steps carefully and taking care not to apply a side load to the upper/lower tube assembly before the Damping Tube Assembly has been installed.

5.6 Pinching/Cutting of Hands and Bumps to the Head, Etc.

The individual pieces of the baffle are thin pieces of metal, and though the edges have been beveled, there is a potential to receive cuts if parts are handled improperly. Each team member should inspect to their satisfaction the prospective part to be handled to determine if that part has a potentially hazardous sharp edge. Hands may also be pinched when assembling parts to one another, but this can be mitigated with proper attention to handling the parts.
During the assembly inside the vacuum chamber, personnel should be mindful of where they stand and move as to not damage nearby objects and bump their heads, knees, etc. Damage from accidental bumps can be mitigated by being spatially aware of the working area and by spotting one another.

5.7 Vacuum Contamination

The vacuum system will be opened during this installation process and has the potential to be contaminated. All work must be done in positive pressure clean rooms and all personnel must be garbed in appropriate Class A garb. Standard Class A procedures must be practiced at all times.
Should a glove tear due to cuts, there is a potential to cause vacuum contamination problems.

6 Arm Cavity Baffle Hazard Analysis Severity Table

Item #	Hazard	Cause	Effect	Unmitigated Severity	Unmitigated Probability Level	Unmitigated Risk Index	Comment	Mitigation	Mitigation Severity	Mitigated Probability Level	Mitigated Risk Index
1	Strain from lifting heavy assembly	Lifting heavy assembly without support	Injury to personnel, damage to equipment	marginal	occasional	3C	Total assembly weighs 95 to 130 lbs (without or with weights), CA/OSHA one man lift value is 50 lbs	At least three people must lift assembly	minor	improbable	4E
2	Sudden release of tensioned springs	spontaneous failure of flexure, or overstress of flexure by applying a heavier than design load	Injury to personnel, damage to equipment	critical	remote	2D	Blade spring has ~140 lbs of load	Blade spring is constrained in the tooling and assembly to limit motion; Overload is prevented once the Damping Tube subassembly is installed (motion limiters); Safety glasses will prevent eye injury in the case of fast moving part during assembly.	minor	remote	4D
3	Damage to quad suspension or mirror	Dropping tools, or touching the mirror with any object or body part	Injury to quad suspension assembly	critical	probable	2B	Quad assembly has critical alignment and fragile fused silica fiber suspension	1) Tethers will limit swinging motion of the baffle until it is secured to the suspension mechanism. 2) A rigid barrier will be erected between the quad suspension and the ACB 3) Awareness of staying clear of the quad sus	minor	remote	4D
4	Dropped parts	Slipping from personnel hands	Damage to parts, feet and toes	minor	probable	4B	Maximum weight is 130 lbs.	Personnel are to wear steel toes shoes during installation	minor	improbable	4E
5	Overstress/ damage of the flexure	Personnel applying excessive torque, or lateral load to the tube assembly	Damage to flexure	marginal	occasional	3C		Careful procedure with prescribed torque value	minor	remote	4D

6	Pinching/cutting of hands and bumps to the head	Injured by dog clamps, touching sharp edges, accidentally walking into suspension	Minor head injury Minor finger and hand injury	minor	probable	4B		Wear head gear when practical during installation	minor	improbable	4E
7	Vacuum Contamination	Exposed vacuum chamber; removal of covers/wraps	Damage to environment	marginal	occasional	3C		All parts handled in clean rooms outside of vacuum; all personnel dressed in Class A approved garb	minor	remote	4D

Hazard Severity	Category	Definition
Catastrophic	1	Death or permanent total disability, system loss, major property damage or severe environmental damage.
Critical	2	Severe injury, severe occupational illness, major system or environmental damage.
Marginal	3	Minor injury, lost workday accident, minor occupational illness, or minor system or environmental dam
Minor or Negligible	4	Less than minor injury, first aid or minor supportive medical treatment type of occupational illness, or less than minor system or environmental damage.

Probability	Level	Individual Item
Frequent	A	Likely to occur frequently or continuously experienced.
Probable	B	Will occur several times in the life of an item.
Occasional	C	Likely to occur some time in the life of an item.
Remote	D	Unlikely but possible to occur in the life of an item.
Improbable	E	So unlikely, it can be assumed occurrence may not be experienced.

SEVERITY OF CONSEQUENCE	PROBABILITY				
	E Improbable	D Remote	C Occasional	B Probable	A Frequent
1 Catastrophic					
2 Critical					
3 Marginal					
4 Negligible					

Hazard Risk Index	Risk Code Criteria
1A, 1B, 1C, 2A, 2B, 3A	Unacceptable
1D, 2C, 2D, 3B, 3C	Undesirable (Directorate decision required)
1E, 2E, 3D, 3E, 4A, 4B	Acceptable with review by Directorate
4C, 4D, 4E	Acceptable without review